AN EVALUATION OF SEISMIC HAZARD IN LA HISPANIOLA, AFTER THE 2010 HAITI EARTHQUAKE

B. Benito[1], D. Belizaire[2], Y. Torres[1], J.J. Martinez-Diaz[3], V. Huerfano[4], E. Polanco[5], R. Garcia[1], P. Crende[1], A.R. Serna[1], F. Zevallos[4]

1 - Technical University of Madrid; 2 - National Observatory of the Environment and Vulnerability of Haiti; 3 - Complutense University of Madrid; 4 - Puerto Rico Seismic Network; 5 - Universitary Seismological Institute of Dominican Republic

Earthquake Engineering Researching Group

ABSTRACT

An evaluation of the seismic hazard in La Hispaniola Island has been carried out, as part of the cooperative project SISMO-HAITI, supported by the Technical University of Madrid (UPM) and developed by several Spanish Universities, the National Observatory of Environment and Vulnerability) ONEV of Haiti, and with contributions from the Puerto Rico Seismic Network (PRSN) and University Seismological Institute of Dominican Republic (ISU). The study was aimed at obtaining results suitable for seismic design purposes. It started with the elaboration of a seismic catalogue for the Hispaniola Island, requiring an exhaustive revision of data reported by more than 20 seismic agencies, apart from these from the PRSN and ISU. The final catalogue contains 96 historical earthquakes and 1690 instrumental events, and it was homogenized to moment magnitude, Mw. Seismotectonic models proposed for the region were revised and a new regional zonation was proposed, taking into account geological and tectonic data, seismicity, focal mechanisms, and GPS observations.

In parallel, attenuation models for subduction and crustal zones were revised in previous projects and the most suitable for the Caribbean plate were selected. Then, a seismic hazard analysis was developed in terms of peak ground acceleration, PGA, and spectral accelerations, SA (T), for periods of 0.1, 0.2, 0.5, 1 and 2s, using the Probabilistic Seismic Hazard Assessment (PSHA) methodology. As a result, different hazard maps were obtained for the quoted parameters, together with Uniform Hazard Spectra for Port au Prince and the main cities in the country. Hazard deaggregation was also carried out in these towns, for the target motion given by the PGA and SA (1s) obtained for return periods of 475, 975 and 2475 years. Therefore, the controlling earthquakes for short- and long-period target motions were derived. This study was started a few months after the 2010 earthquake, as a response to an aid request from the Haitian government to the UPM, and the results are available for the definition of the first building code in Haiti.

INPUTS

1. SEISMIC CATALOGUE

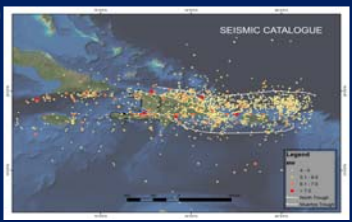

Figure 1. Seismic catalogue of the study

Figure 1 shows the epicenters of the seismic catalogue configured in this study, containing almost 1800 registers (both historical and instrumental events). Main Agencies: PRSN , ISU and more than other 20 agencies (USGS, NOAA, ISC, NRC…). The catalogue has been homogenized to Mw adopting the empirical relations proposed by Bozzoni et al. (2011), and declustered to remove aftershocks and foreshocks, as it is required by zoning methods. Correction of completeness has also carried out.

2. SOURCE MODELS

In the study, both faults and zones have been used as seismogenic sources. The faults included in this study as independent elements are Enriquillo, Septentrional and Matheux-Neiba (figure 2). For the zones, two tectonic settings have been defined according to the depth of the crustal (focal depth lower than 50 km, figure 3) and subduction (focal depth greater than or equal to 50 km, figure 4) seismicity.

Figure 2. Main faults

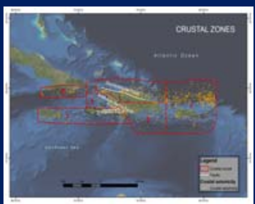

Figure 3. Crustal zones

Figure 4. Subduction zones

Faults have been combined with crustal zones. The recurrence models used has been (figure 5): the following:

- For the zones: Gutenberg-Richter law (G-R) estimated from seismicity with the maximum likelihood method
- For the faults: G-R and the characteristic earthquake model (CEM), both derived from slip-rate (GPS data, Calais et al., 2002; Frankel et al., 2011), following the approach of Frankel et al (1996).

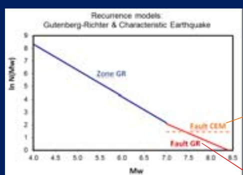

Figure 5. Combination of recurrence models

3. ATTENUATION LAWS

As there are not ground motion prediction equations (GMPE) developed specifically for the Caribbean region, models derived from areas with similar tectonic characteristics have been adopted. Some of them have been calibrated with Central America strong motion data (Benito et al., 2012).

- For crustal zones:
Boore and Atkinson (2011), Kanno et al (2006), and Zhao et al (2006)
- For subduction zones:
Lin and Lee (2008) and Zhao et al (2006)

Six combinations "GMPE crustal + GMPE subduction" have been included in the logic tree, weighted according to their trustworthiness. The characteristics of the selected GMPE are shown in table 1 and figure 6.

Table 1. Characteristics of the GMPE

MODEL	TYPE OF SOURCE	PARAMETERS	SOURCE OF DATA	TYPE MAG.	RANGE MAG.	TYPE DIST	RANGE DIST.
Kanno et al (2006)	Intraplate, crustal	Mag., dist., soil type	Central America	Mw	4.0-9.0	Rrup	0-200 km
Zhao et al (2006)	Interfase, intraplate, crustal	Mag., dist., H, focal mecanism, soil type	Japan	Mw	5-8.2	Rrup	10-300 km
Lin and Lee (2008)	Interfase, intraplate,	Mag., dist., H, focal mecanism, soil type	Taiwan	Mw	5.3-8.1	Dhyp	15-630 km
Boore and Atkinson (2011)	Crustal	Mag., dist., focal mecanism, soil type	Worldwide	Mw	5.0-8.0	Rjb	< 200 km

Note: Mag.: magnitude; Dist.: distance; H: depth; Mw: moment magnitude; Rrup.: Rupture distance; Dhyp.: Hypocentral distance; Rjb.: Joyner and Boore distance.

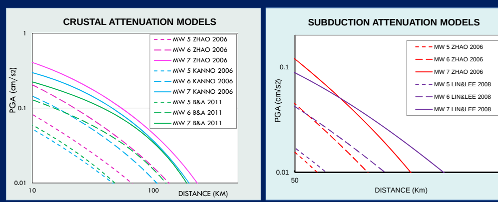

Figure 6. GMPE selected models for crustal (left) and subduction (right)

LOGIC TREE AND RESULTS

1. LOGIC TREE

A logic tree (figure 7) with two nodes has been considered, for taking into account epistemic uncertainty related to the recurrence models adopted for faults (G-R or CEM) and the GMPE's combinations (crustal + subduction). In any case faults are combined with zones modeled by G-R.

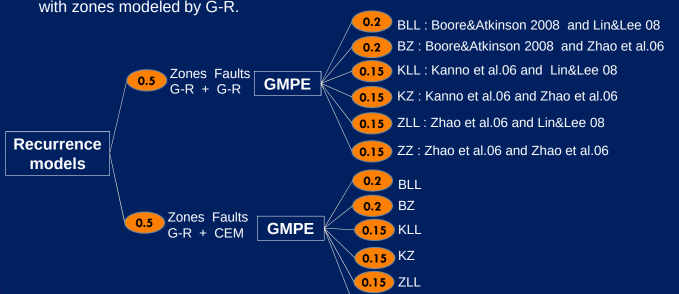

Figure 7. Logic tree(weights in orange ellipse)

2. HAZARD MAPS

Seismic hazard has been estimated by using CRISIS (www.iingen.unam.mx), in terms of PGA and SA (T) for T = 0.1, 0.2, 0.5, 1 and 2 s on rock conditions; and for return periods: of 475, 975 and 2475 years. Expected PGA maps are shown in figure 9 (mean values of the logic tree).

As antecedents of these results, previous maps obtained by Frankel et al. (2011) and the Dominican Republic Seismic Code are shown in figure 8. The morphology of our maps is quite similar to those of the Frankel's map, but our PGA values are significantly lower, being more consistent with the ones given by the Dominican Republic Code. As a general trend, the PGA obtained in this study for 975 years are similar to those of the Frankel's map for 475 years.

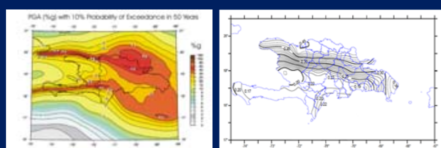

Figure 8. Hazard maps for PGA and RP 457 yrs. from Frankel et al. (2011) (left) and Dominican Republic Seismic Code (right)

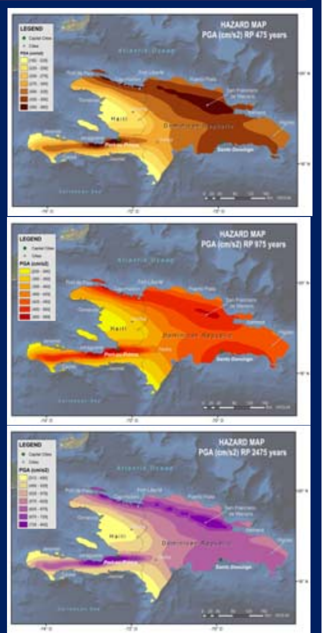

Figure 9. Hazard maps

SUMMARY AND CONCLUSIONS

A complete PSHA study has been carried out for La Hispanola, in the frame of a cooperative project with Haiti, after the 2010 earthquake. A seismic catalogue was configured with data of Dominican Republic, Puerto Rico and other 20 agencies, being the first catalogue including Haiti homogenised to Mw. An hybrid model using zones and faults has been used, considering two tectonic regimes: crustal and subduction. Recurrence models were estimated: 1. for zones from the seismicity fit to Gutenberg Richter laws and 2. for faults from slip rate derived of GPS observations adopting G-R or Characteristic Earthquake Model. GMPE suitable for Caribbean plate were chose and six combinations (GMPE crustal + GMPE subduction) were included in a logic tree.

The hazard maps obtained show maximum PGA values in NE of Dominican Republic (affected by crustal and subduction scenarios), North Haiti (around Septentrional fault) and South Haiti (Enriquillo and Matheux faults). PGA values for return period of 475 years are consistent with the ones given by the Dominican Republic Code, ranging between (162-382 cm/s2) . These PGA are notably lower than the ones obtained by Frankel et al (2011), in a preliminary study, reaching 600 cm/s2. However the morphology of both maps, the ones by Frankel and this study, is quite similar in spite of using different catalogue, zoning and GMPE's. It may be explained because these aspects are more sensible to the location of faults, when hybrid models are used.

The results are available for the first Building Code in the country.

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CONTACT: mariabelen.benito @upm.es
+ 34 913366441